Hale School
Year 12 Semester 1 Examination, 2018

Write your name below:

_____

Yr12 ATAR CHEMISTRY UNIT 3

Circle your teacher's initials:

PRB KF AD

TIME ALLOWED FOR THIS PAPER

Reading time before commencing: Ten minutes
Working time for paper: Three hours

For Examiners only	
Section 1	
Section 2	
Section 3	
Total	

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

TO BE PROVIDED BY THE SUPERVISOR

This Question/Answer booklet for Sections 1 & 2.
A separate Question/Answer booklet for Section 3.
A separate Multiple Choice Answer sheet for Section 1.
A Chemistry Data Sheet.

TO BE PROVIDED BY THE CANDIDATE

Standard Items: Pens, pencils, eraser, ruler

Special Items: A calculator satisfying the conditions set by the Curriculum Council, and a '2B' pencil for the separate Multiple Choice Answer sheet.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room.

It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. Please check carefully, and if you have any unauthorised material with you, hand it to the supervisor **BEFORE** reading any further.

INSTRUCTIONS TO CANDIDATES

This paper consists of **THREE SECTIONS** as follows:

SECTION 1 contains **25 questions worth 2 marks each.** It is the multiple choice section.

Answer **ALL** questions in Section 1 on the Separate Multiple Choice Answer Sheet. Use a **'2B' PENCIL**. **DO NOT USE A BALL POINT OR INK PEN**. If you consider that two or more of the alternative answers are correct then select the BEST alternative. Marks will **NOT** be deducted for incorrect answers. This part is worth 50 marks and should take about 45 minutes.

Do not use pencil for Sections 2 & 3.

SECTION 2 contains **11 short answer questions**. You should answer **ALL** the questions. The answers are to be written in the spaces provided in this Examination booklet. This part is worth 72 marks and should take about 60 minutes.

SECTION 3 contains **6 extended response and calculation questions**. You should answer **ALL** the questions in detail in the **separate question/answer booklet provided.** This part is worth 90 marks and should take about 75 minutes.

At the end of the examination make sure that your **name** is on this Examination paper, the separate Question/Answer Booklet for Section 3 and your Multiple Choice Answer Sheet.

SPECIAL INSTRUCTIONS

Chemical Equations

For full marks, chemical equations should refer only to those species consumed in the reaction and any new species produced. These species may be **ions** [for example $Ag^+(aq)$], **molecules** [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$, $CH_3COOH(aq)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	45	50	24
Section Two: Short answer	11	11	60	72	34
Section Three: Extended answer	6	6	75	90	42
			Total	**212**	**100**

See next page

See next page

Section One: Multiple-choice **24% (50 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet Provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question

Suggested working time: 45 minutes

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1. Which of the following pairs of reagents could not be mixed to make a buffer solution?

   (a) $NaOH(aq)$ and $CH_3COOH(aq)$

   (b) $NaCH_3COO(s)$ and $CH_3COOH(aq)$

   (c) $NaOH(aq)$ and $NaCH_3COO(s)$

   (d) $NH_4Cl(s)$ and $NH_3(aq)$

2. Which of the following processes is exothermic?

   (a) $2Rb^+(g) + S^{2-}(g) \rightarrow Rb_2S(s)$

   (b) $O_3(g) \rightarrow 3O(g)$

   (c) $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$

   (d) $CO_2(s) \rightarrow CO_2(g)$

3. When comparing 1.00 L of 0.100 mol L^{-1} nitric acid with 1.00 L of 0.100 mol L^{-1} ethanoic acid, which of the following statements is true?

   (a) Both acids react at the same rate with calcium carbonate solid.

   (b) The ethanoic acid would contain less hydroxide ions than the nitric acid

   (c) Both acids would require the same volume of 0.100 mol L-1 NaOH solution for neutralisation

   (d) The equilibrium constant for the hydrolysis of nitric acid is smaller than that for ethanoic acid

4. Nitrous acid ionises in water according to the following equation:

   $$HNO_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + NO_2^-(aq)$$

   450 mL of water is added to 50 mL of nitrous acid solution at constant temperature. As a result of the dilution, at the new equilibrium, compared with the original solution, the

   (a) equilibrium constant for the reaction decreases

   (b) $[H_3O^+]$ in the solution is greater

   (c) pH of the solution is greater

   (d) the amount in moles of H_3O^+ decreases

See next page

5. Consider the following indicators and their corresponding colour ranges in the table below:

Indicator name	
methyl orange	red → ← yellow
bromothymol blue	yellow → ← blue
azolitmin	red → ← blue
cresol red	yellow → ← red
Malachite green	yellow → ← green

Use the information in the table to decide which of the following are correct:

(i) Bromothymol blue and azolitmin will show the same colour in 0.001 KOH(aq)

(ii) Methyl orange is a good indicator for the titration of ammonia against hydrochloric acid solution

(iii) Azolitmin is able to distinguish between an aqueous solution of potassium carbonate and an aqueous solution of sodium cyanide.

(iv) Malachite green can distinguish a between a 1.0 mol L^{-1} sulfuric acid solution and a 1.0 mol L^{-1} carbonic acid solution

(a) (ii) and (iv)

(b) (ii), (iii) and (iv)

(c) (i), (ii) and (iv)

(d) (i) and (ii) only

6. A saturated solution of calcium chromate consists of a yellow solution with a few yellow crystals of calcium chromate settled at the bottom of the solution.

$$CaCrO_4(s) \rightleftarrows Ca^{2+}(aq) + CrO_4^{2-}(aq)$$

What is observed when a few drops of concentrated calcium chloride solution is added to the mixture?

(a) The yellow crystals dissolve and the solution becomes a darker yellow

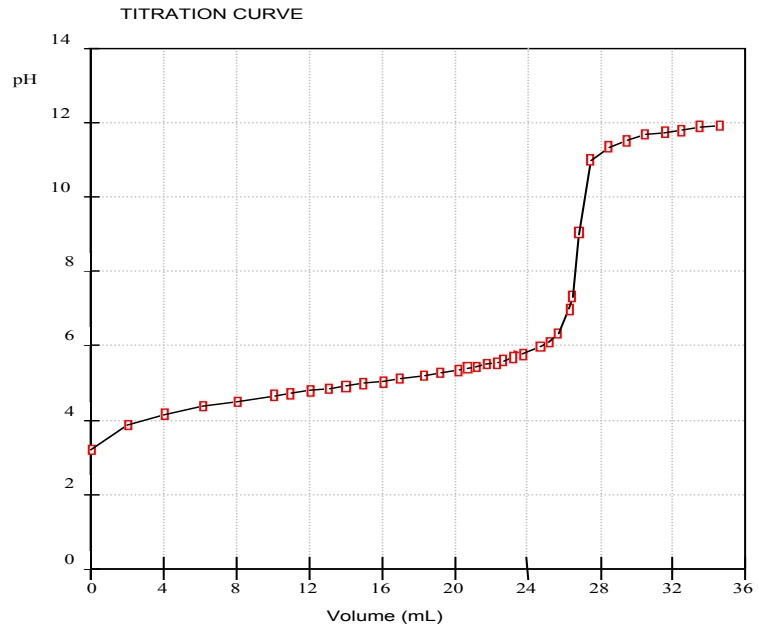
(b) More yellow crystals form and the solution becomes a paler yellow

(c) More yellow crystals form and the solution turns orange

(d) The yellow crystals dissolve and the solution fades

See next page

7. Consider the following titration curve:



Which of the following statements is **not correct** concerning this titration?

(a) The titration is between a weak acid and a strong base

(b) The equivalence point is basic due to the hydrolysis of the anion of the salt, producing hydroxide ions

(c) The buffer region occurs when approximately 12.5 mL of base added from the burette

(d) If phenolphthalein is used as the indicator the end point will not correspond with the equivalence point.

8. Nitrogen monoxide and chlorine react according to the equation:

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g) \qquad \Delta H = -38 \text{ kJ/mol}$$

The activation energy for the forward reaction is 62 kJ/mol. The activation energy for the reverse reaction is:

(a) –62 kJ/mol

(b) 24 kJ/mol

(c) 38 kJ/mol

(d) 100 kJ/mol

9. In which of the following reactions does the atom in **bold** show the greatest change in oxidation number?

(a) $\mathbf{Mn}O_4^-$ to Mn^{2+}

(b) $\mathbf{Mn}O_2$ to $Mn(OH)_3$

(c) $\mathbf{Pb}O_2$ to $PbSO_4$

(d) $\mathbf{V}O_2^+$ to VO^{2+}

See next page

10. According to the Standard Reduction Potential Table, which of the following partially completed half reactions is able to oxidise Pb (s) to Pb^{2+} (aq), but is not able to oxidise aqueous iodide ions to solid iodine?

    (a) $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$

    (b) $O_2(g) + 2H_2O(l) + 4e^-$

    (c) $Br_2(l) + 2e^-$

    (d) $2H_2O(l) + 2e^-$

11. The cell reaction occurring in some 'button' batteries, as current is drawn, is:

    $$Ag_2O(s) + Zn(s) + H_2O(l) \rightarrow 2Ag(s) + Zn(OH)_2(s)$$

    Which one of the following statements about the electrochemical cell is correct?

    (a) The anode is made of zinc and is oxidised.

    (b) Silver forms the anode and is oxidised.

    (c) Zinc forms the cathode and is reduced.

    (d) Silver oxide forms the anode and is oxidised.

12. For a reversible reaction, catalysts alter

    (a) The heat of reaction for the forward reaction.

    (b) The size of the equilibrium constant.

    (c) The time taken for an equilibrium to be established.

    (d) The yield achieved at equilibrium.

13. An indicator is red if the pH is less than 4.4 and yellow if the pH is greater than 6.2. The indicator is placed in 0.10 mol L^{-1} solutions of KCN, H_2SO_4 and $MgCl_2$. The colours of the solutions are

	KCN	**H_2SO_4**	**$MgCl_2$**
(a)	Red	Yellow	Yellow
(b)	Yellow	Red	Yellow
(c)	Red	Yellow	Red
(d)	Yellow	Red	Red

14. In which one of the following equations is the species in **bold** acting as a base?

    (a) $\mathbf{H_2O} + NH_3 \rightleftharpoons NH_2^- + H_3O^+$

    (b) $\mathbf{HCO_3^-} + NH_3 \rightleftharpoons CO_3^{2-} + NH_4^+$

    (c) $H_2PO_4^- + \mathbf{CH_3COOH} \rightleftharpoons H_3PO_4 + CH_3COO^-$

    (d) $\mathbf{H_2CO_3} + 2\,Na \rightleftharpoons 2\,Na^+ + CO_3^{2-} + H_2$

See next page

15. An acid-base titration is performed to determine the concentration of a sodium hydroxide solution. An aliquot of the sodium hydroxide solution is pipetted into a conical flask, while a standardised solution of propanoic acid is delivered from the burette. A student uses the indicator bromophenol blue, which changes colour at about pH 4. Which one of the following best explains why this is the incorrect choice of indicator?

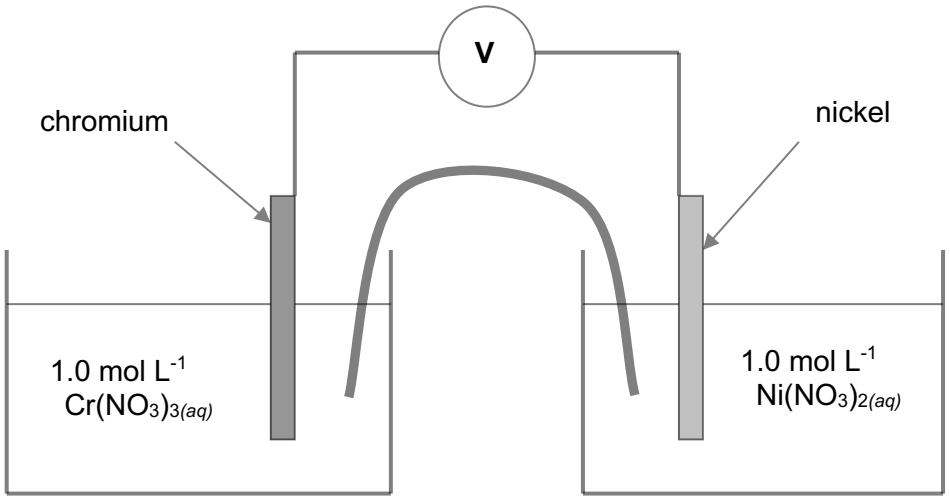
    (a) Too much acid will be delivered and the calculated sodium hydroxide concentration will be too high.

    (b) Too much acid will be delivered and the calculated sodium hydroxide concentration will be too low.

    (c) Not enough acid will be delivered and the calculated sodium hydroxide concentration will be too high.

    (d) Not enough acid will be delivered and the calculated sodium hydroxide concentration will be too low

*Consider the following electrochemical cell to answer Questions **16** and **17***



16. Which of the following statements is correct?

    (a) The nickel anode will increase in mass

    (b) The electrode with a negative polarity will decrease in mass

    (c) The concentration of $Cr^{3+}(aq)$ will decrease as the cell discharges

    (d) Cations will move through the salt bridge towards the chromium half-cell

17. The main reason that an aqueous solution of potassium nitrate is suitable for use in a salt bridge is:

    (a) $K^{+}(aq)$ is a weak reductant

    (b) $NO_3^{-}(aq)$ ions cannot be further oxidised

    (c) Potassium and nitrate salts are always soluble in water

    (d) It is available in pure form and does not react with the atmosphere

See next page

18. For which of the following conversions is an oxidising agent required?

(a) $2H^+(aq) \rightarrow H_2(g)$

(b) $2Br^-(aq) \rightarrow Br_2(aq)$

(c) $SO_3(g) \rightarrow SO_4^{2-}(aq)$

(d) $MnO_2(s) \rightarrow Mn^{2+}(aq)$

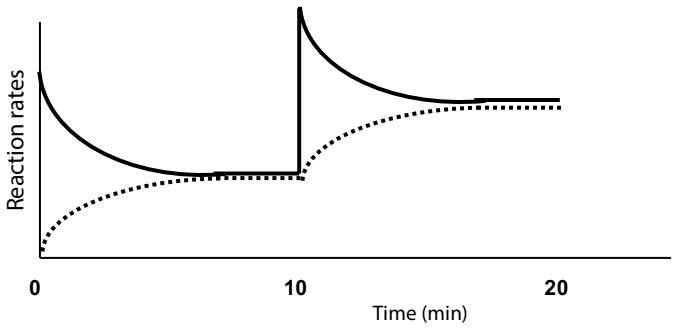
19. A titration was carried out to determine the vitamin C content of orange juice. 20.0 mL of diluted orange juice was pipetted into a conical flask. The burette was filled with standard sodium hydroxide solution. The correct choice for the final rinse of the glassware is

	Pipette	Burette	Conical Flask
(a)	distilled water	NaOH(aq)	diluted orange juice
(b)	diluted orange juice	distilled water	distilled water
(c)	distilled water	distilled water	diluted orange juice
(d)	diluted orange juice	NaOH(aq)	distilled water

20. Some ammonia gas is pumped into a sealed container that can have its volume increased or decreased. The reversible decomposition reaction begins immediately.

$$2\ NH_3(g) + 92\ kJ \rightleftarrows N_2(g) + 3\ H_2(g)$$

The forward and reverse reaction rates are measured and after 10 minutes a change is made to the gas system. The reaction rates are measured for a further 10 minutes. The graph at right shows how the rates of the forward and reverse reactions changed during the 20 minutes.



What change was made to the system after 10 minutes?

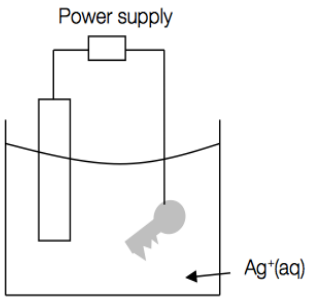
(a) The volume of the gas mixture was decreased

(b) More ammonia was pumped in

(c) The mixture was heated

(d) Some hydrogen was pumped in

21. A student decided to silver plate their locker key, as shown at right. Which of the following statements is correct ?



(a) the key is the cathode

(b) the cathode is silver metal

(c) the key is the anode

(d) electrons flow anticlockwise from the key

See next page

The following two questions **22** and **23** are about a step in the production of nickel at the Kwinana refinery. The reaction is represented by the following equation:

$$Ni(NH_3)_4^{2+}(aq) + H_2(g) \rightleftarrows Ni(s) + 2NH_4^+(aq) + 2NH_3(g)$$

22. Which of the following conditions will increase the **yield** of nickel?

(a) removing the nickel as soon as it forms

(b) increasing the partial pressure of ammonia

(c) increasing the partial pressure of hydrogen

(d) increasing the total pressure of the system

23. Which of the following will bring about the **fastest rate** of formation of nickel?

(a) removing the nickel as soon as it forms

(b) increasing the partial pressure of ammonia

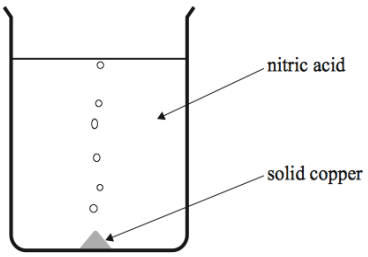
(c) increasing the partial pressure of hydrogen

(d) decreasing the total pressure of the system

24. Copper reacts with concentrated nitric acid according to the following equation.

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions. The **major** reason for this is that:



(a) the nitric acid is only partially ionised

(b) not all the reactant particles have the minimum kinetic energy required for a successful collision

(c) copper is an unreactive metal

(d) the reaction is endothermic

25. Using the standard reduction potential table predict which one of the following reactions could possibly occur spontaneously?

(a) $I_2 + 2Cl^- \rightarrow Cl_2 + 2I^-$

(b) $Cu^{2+} + H_2O_2 \rightarrow Cu + 2H^+ + O_2$

(c) $H_2C_2O_4 + Br_2 \rightarrow 2\,Br^- + 2CO_2 + 2H^+$

(d) $Cr_2O_7^{2-} + 11\,H^+ + 3\,Cl^- \rightarrow 2\,Cr^{3+} + 4\,H_2O + 3\,HClO$

End of Section One

See next page

Section Two: Short answer **34% (72 Marks)**

This section has 11 questions. Answer all questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes

Question 26 **(4 marks)**

For each of the following reactions, give full observations. Include any colour changes, formation of a solid or evolution of a gas. If there is no reaction you need to state this.

(a) A potassium permanganate solution is added, dropwise, into an acidified solution of hydrogen peroxide. (2 marks)

_____

_____

(b) Cobalt carbonate is added to dilute hydrochloric acid solution. (2 marks)

_____

_____

Question 27 **(3 marks)**

A 0.00100 mol L^{-1} solution of hydrochloric acid and a 0.0560 mol L^{-1} solution of hydrofluoric acid both have a pH of 3.0. Explain fully why both solutions have the same pH.

See next page

Question 28 **(4 marks)**

Both sodium carbonate and sodium hydroxide react stoichiometrically with hydrochloric acid. Anhydrous sodium carbonate is a good primary standard often used in acid-base volumetric analysis to standardise hydrochloric acid solutions. Sodium hydroxide is not a primary standard substance.

(a) Explain why sodium hydroxide is not used as a primary standard substance. (2 marks)

(b) Distinguish between the terms 'equivalence point' and 'end point' of a titration. (2 marks)

Equivalence point

End point

Question 29 **(8 marks)**

Consider 100 mL of a solution at 25°C and 100 kPa which contains the following equilibrium mixture.

$$CuCl_4^{2-}(aq) + 6H_2O(l) \rightleftarrows Cu(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \qquad \Delta H = +23 \text{ kJ}$$

Write 'increase', 'decrease' or 'no change' in the table to indicate the effect of the given change on the equilibrium yield and the rate of the forward reaction when equilibrium is re-established.

Imposed change	Effect on yield of $Cu(H_2O)_6^{2+}$	Effect on rate of forward reaction
The temperature is decreased to 5°C		
100 mL of distilled water is added		
The pressure is doubled		
A few drops of concentrated lead nitrate solution are added		

See next page

Question 30 **(8 marks)**

Water is often purified by treatment with ozone. Any bromide ions present are converted to colourless bromate ions, BrO_3^-. Bromate ions are toxic, and so must be removed.

(a) (i) Write the appropriate oxidation numbers on the lines under the equation. (2 marks)

$$Br^- + O_3 \rightarrow BrO_3^-$$

___ ___ ___ ___

(ii) Identify the reducing agent and explain your choice using your answers to (i). (2 marks)

Reducing agent _____

Explanation _____

_____

_____

(b) One way of removing the toxic bromate ions is to react the bromate ions with iodide ions. Bromide ions are reformed and the solution turns brown.

Deduce the oxidation and reduction half equations and write the balanced redox equation for this reaction. (4 marks)

Oxidation half equation
Reduction half equation
Balanced redox equation

See next page

Question 31 **(9 marks)**

An electrochemical cell is set up under standard conditions of temperature, pressure and concentration, as sketched below.

The half-cells represented in the cell, and their respective reduction potentials, are:

$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$ $E^0 = +0.54$ V

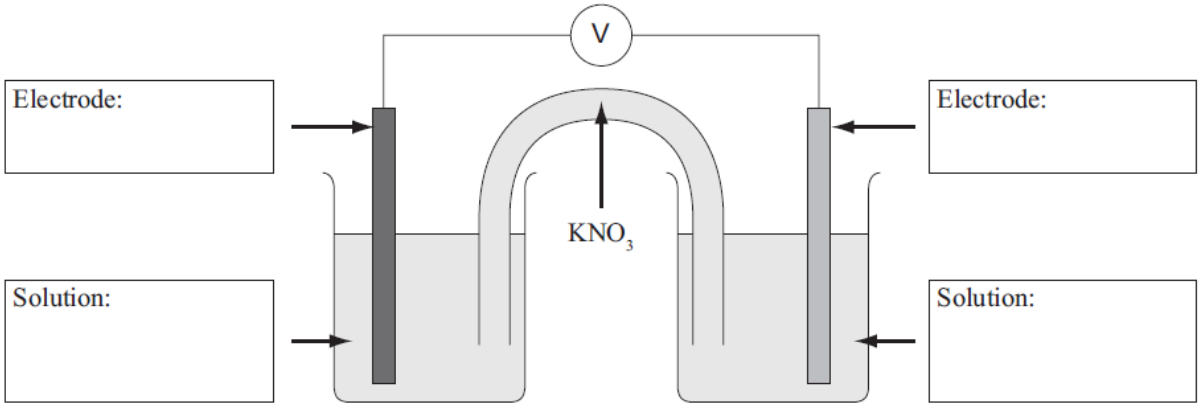
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $E^0 = +0.80$ V

(a) Complete the diagram below by

i. Identifying the **solutions** and **electrode materials** (3 marks)

ii. Showing the **direction of electron flow** (1 mark)

iii. Labelling the **anode** and the **cathode** (1 mark)



(b) Describe the **observations** at each electrode: (2 marks)

Anode:_____

_____

Cathode:_____

_____

(c) What is the function of the salt bridge in an electrochemical cell? (1 mark)

_____

_____

(d) During the operation of an electrochemical cell, why is it important that the anode and cathode do not come into contact with each other? (1 mark)

_____

_____

See next page

Question 32 **(10 marks)**

(a) Calculate the pH of the final solution when 100.0 mL of HNO_3 solution with a pH of 1.5 is mixed with 35.0 mL of 0.20 mol L^{-1} $Ba(OH)_2$ solution. (6 marks)

(b) 50.0 mL of distilled water is added to 10.0 mol L^{-1} HNO_3 solution to achieve a final concentration of 2.00 mol L^{-1}. What volume of the 10.0 mol L^{-1} HNO_3 is required and what is the final volume of the diluted acid? (4 marks)

See next page

Question 33 **(6 marks)**

Sodium arsenate solution can react with potassium iodide solution as represented by the following equation.

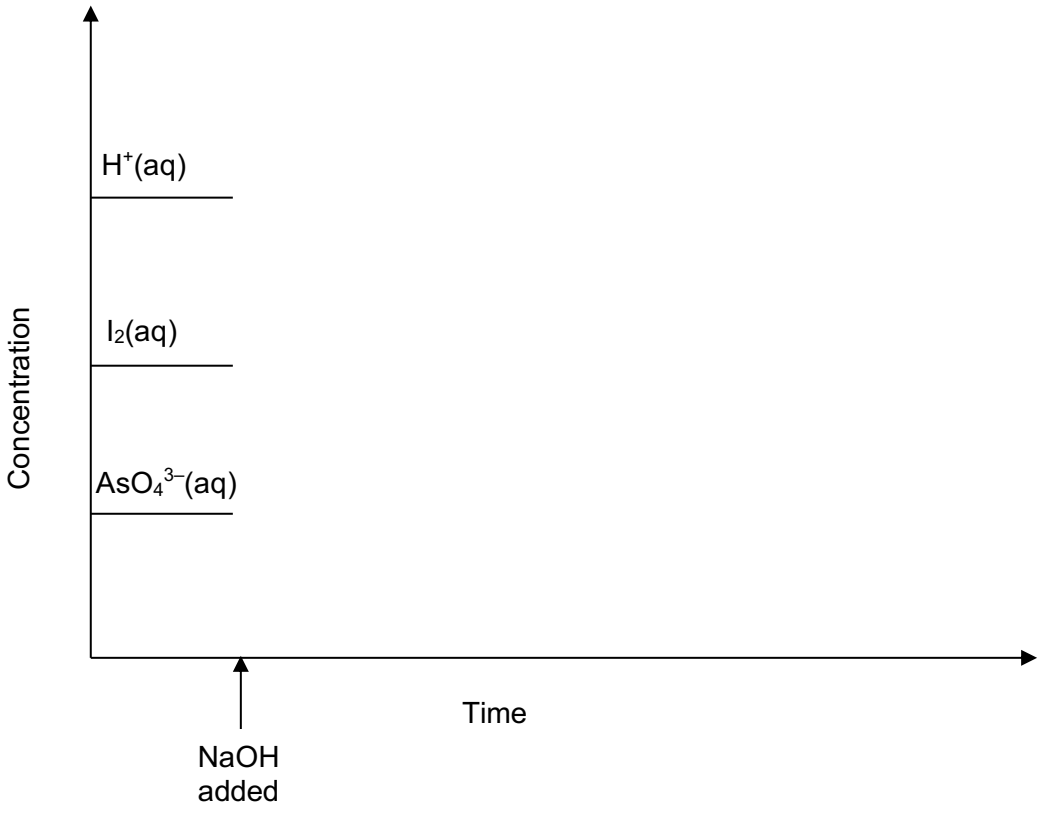
$$AsO_4^{3-}(aq) + 2I^-(aq) + 2H^+(aq) \rightleftarrows AsO_3^{3-}(aq) + I_2(aq) + H_2O(l)$$

Iodine is brown in aqueous solution. None of the other species are coloured. The equilibrium mixture is brown.

(a) Complete the table below by describing the expected observations as the system adjusts to the imposed changes. (2 marks)

Change imposed	Observations
Addition of a few drops of concentrated sodium iodide solution	
Doubling the volume by adding distilled water	

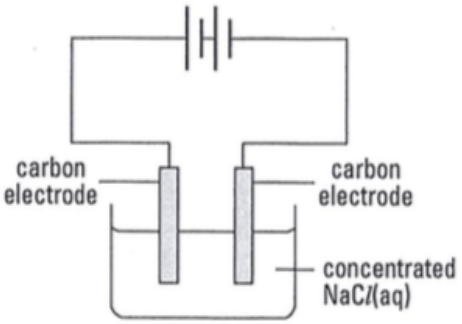
(b) A few drops of concentrated sodium hydroxide solution are added to the equilibrium system. Complete the graph below, indicating qualitatively the concentration changes as the system re-establishes equilibrium. (4 marks)



See next page

Question 34 **(8 marks)**

The diagram below shows an electrolytic cell containing a 1.00 mol L^{-1} NaCl solution with carbon electrodes. Standard conditions of temperature and pressure are assumed.



(a) List all the species that migrate towards or come into contact with the following electrodes:

(i) Anode _____ (1 mark)

(ii) Cathode _____ (1 mark)

(b) Write equations for the most favourable reactions that occur at the:

(i) Anode _____ (1 mark)

(ii) Cathode _____ (1 mark)

(c) What minimum voltage needs to be applied to the sodium chloride cell to ensure that electrolysis occurs? (1 mark)

(d) The carbon anode is replaced with a strip of copper. Describe the changes (or not) in the observations at this electrode. (2 marks)

(e) State another way that the products of this electrolysis process can be altered. (1 mark)

See next page

Question 35 **(6 marks)**

Imagine snacking on a dish of ice cream, washing it down with your favourite soft drink. Delicious! The bacteria in your mouth like it too. The bacteria consume sugar and produce acids. These acids slowly dissolve the hard enamel surface on your teeth, cause plaque and eventually tooth decay.

Tooth enamel is composed of an insoluble mineral called hydroxyapatite, $Ca_5(PO_4)_3OH(s)$

When hydroxyapatite dissolves (**demineralisation),** it separates into calcium, phosphate and hydroxide ions. The dissolved ions can join back together to form the solid hydroxyapatite, this is called **re-mineralisation**. The process of demineralisation is represented as follows:

$$Ca_5(PO_4)_3OH(s) \rightleftarrows 5\ Ca^{2+}(aq) + 3\ PO_4^{3-}(aq) + OH^-(aq)$$

(a) In adult teeth, these two processes (demineralisation and re-mineralisation) are in chemical equilibrium. Explain what is meant by chemical equilibrium in this context. (2 marks)

(b) Write the equilibrium constant expression for the demineralisation reaction. (1 mark)

K =

(c) In adults and children, if too much sugar is eaten, the concentration of **acid increases**. Explain the effect this will have on the equilibrium and consequently the tooth's condition. (2 marks)

(d) The process of demineralisation occurs at pH below 5.5. What is the concentration of hydrogen ions at this pH? (1 mark)

See next page

Question 36 **(6 marks)**

Consider 0.1 mol L^{-1} solutions of:

- Sodium hydroxide
- Ammonium chloride
- Sulphuric acid
- Ethanoic (acetic) acid

(a) Which solution would have the lowest electrical conductivity? Explain. (2 marks)

(b) Which solution would have the highest pH? Explain. (2 marks)

(c) Which solution would have the highest concentration of ions? Explain. (2 marks)

End of Section Two

See next page

Spare answer page

Question number: _____

See next page

Spare answer page

Question number: _____

DO NOT WRITE IN THIS AREA

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See next page

Hale School
Semester One Examination, 2018

Write your name below:

_____

Yr12 ATAR CHEMISTRY
UNIT 3

PRB KF AD

For Examiners only	
Part 3	

Section 3 Question and Answer Booklet.

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See next page

Section Three: Extended answer **42% (90 Marks)**

This section contains six (6) questions. You must answer all questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression.

Final answers to calculations should be expressed to **three (3)** significant figures and include appropriate units.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 75 minutes

Question 37 **(21 marks)**

Chemists and biochemists use the equilibrium constants (K_a) for different acid ionisations to compare their strengths. The K_a values of several naturally occurring, monoprotic, Bronsted-Lowry acids are shown in the table below.

Common name and source	IUPAC name	Structural formula	K_a (at 25˚C)
benzoic acid (from bark resin)	benzoic acid	C_6H_5COOH	6.46×10^{-5}
pyruvic acid (metabolic product)	2-oxopropanoic acid	$CH_3COCOOH$	4.07×10^{-5}
lactic acid (from milk)	2-hydroxypropanoic acid	$CH_3CHOHCOOH$	1.38×10^{-4}

(a) What is meant by the terms **monoprotic** and **Bronsted-Lowry acid**? (2 marks)

monoprotic _____

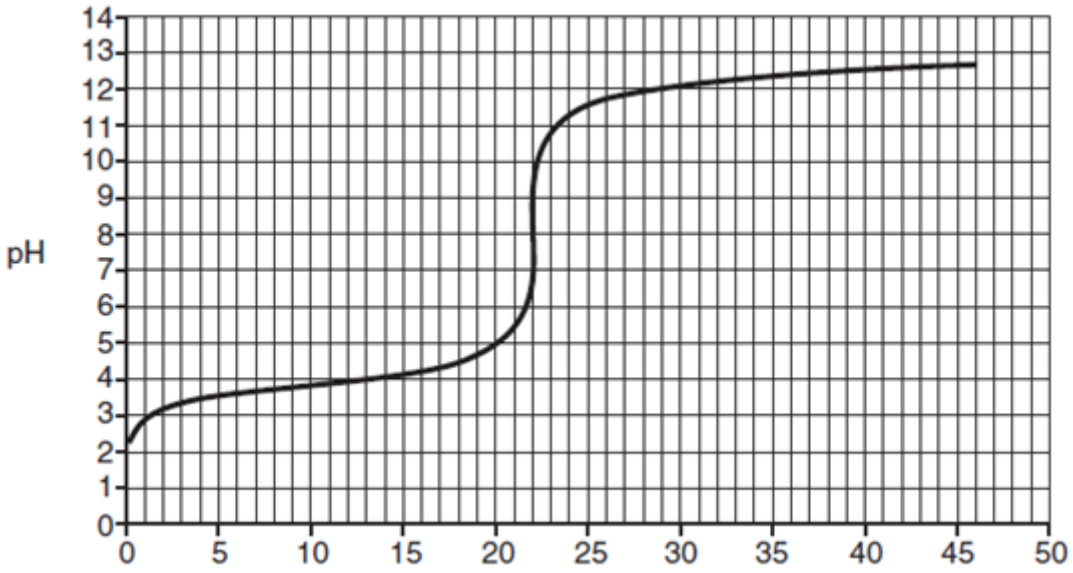
Bronsted-Lowry acid _____

(b) 0.100 mol L^{-1} solutions were prepared of each of the acids in the table above. Which of these solutions has the highest pH? (1 mark)

_____

See next page

Glycolic acid, $HOCH_2COOH$, is a weak, monoprotic acid. A student pipetted a 25.00 mL aliquot of 0.125 mol L^{-1} glycolic acid into a conical flask. The student added sodium hydroxide solution from a burette. A pH meter and data logger were used to measure continuously the pH of the contents of the conical flask. The pH curve that the student obtained is shown below.



(c) Write the equation for the reaction that takes place in the titration. (1 mark)

_____

(d) Determine the concentration, in mol L^{-1}, of the NaOH (2 marks)

(e) List **all** the species (ions and molecules), present at the equivalence point of this titration. List them in order of **decreasing** concentration. (3 marks)

(f) Give two pieces of evidence, from the graph, that demonstrate that glycolic acid is a weak acid. (2 marks)

1. _____

_____

2. _____

_____

See next page

(g) Had the student not had access to a pH meter, what would have been a suitable acid-base indicator to use from the following list? Explain your choice. (2 marks)

Indicator	pH range	Colour change
Alzarin yellow	10.0- 12.0	Yellow to purple
Thymol blue	8.0-9.6	Yellow to blue
Bromocresol purple	5.2-6.5	Yellow to purple

(h) A buffer of glycolic acid and ammonium glycolate is used as a facial cleanser. Explain, using equations, (6 marks)

- How this buffer could be prepared from ammonia solution and glycolic acid.
- How a solution containing glycolic acid and glycolate ions can act as a buffer

(i) Ammonium thioglycolate, $HSCH_2COONH_4$, is the ammonium salt of thioglycolic acid, $HSCH_2COOH$. When ammonium thioglycolate is dissolved in water, an acid-base equilibrium is set up. The equilibrium strongly favours the left-hand side.

In the spaces below, label one conjugate acid-base pair as **Acid 1** and **Base 1** and the other as **Acid 2** and **Base 2** (2 marks)

$$HSCH_2COO^-(aq) + NH_4^+(aq) \rightleftarrows HSCH_2COOH(aq) + NH_3(aq)$$

_____ _____ _____ _____

See next page

Question 38 **(17 marks)**

The water corporation monitors the pH of drinking water very closely. They use pH meters that are calibrated to take the temperature of the water into account when measuring the $[H^+]$, rather than using indicators. Water self-ionises to a small degree.

(a) Write an equation for the self-ionisation of water. (1 mark)

_____

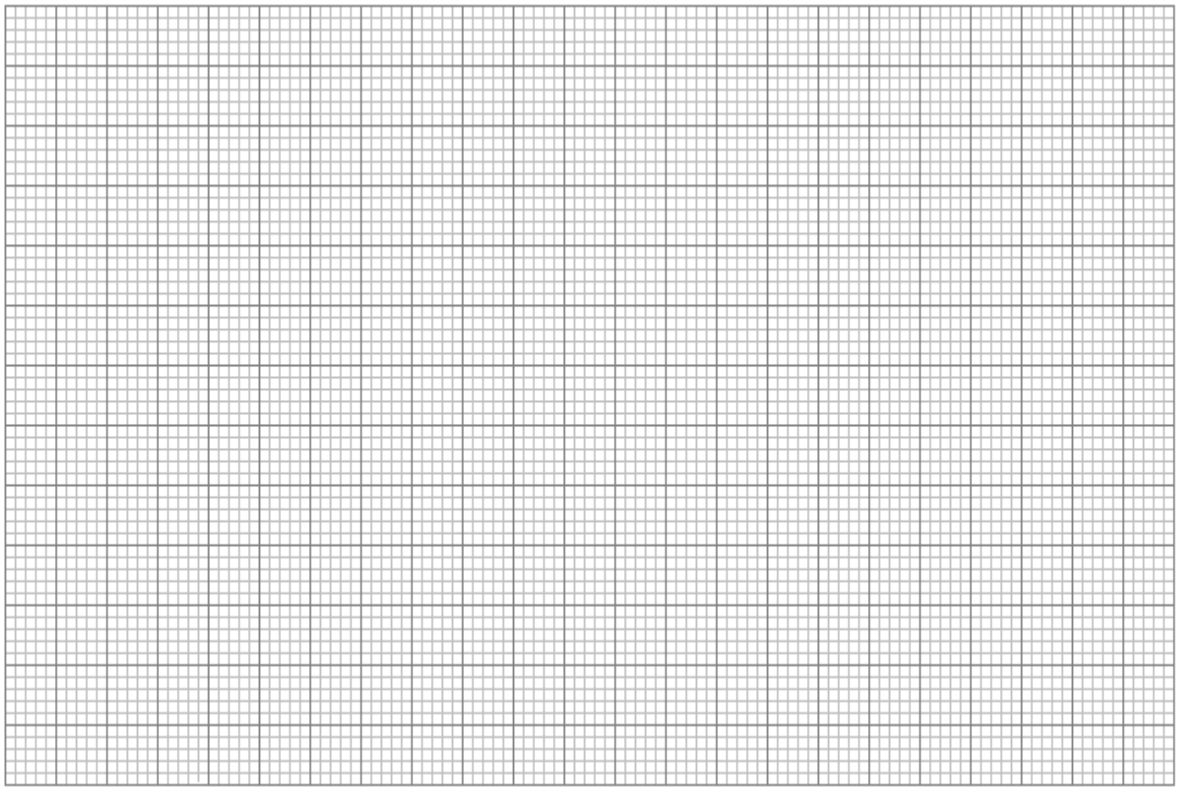
At a given temperature, the self-ionisation of water is at equilibrium. The equilibrium constant expression for this reaction is:

$$K_w = [H^+][OH^-]$$

The values for the equilibrium constant at a range of temperatures are given in the table below.

Temperature (°C)	0	10	20	25	30	40	50	100
Kw (x 10^{-14})	0.11	0.29	0.68	1.01	1.47	2.92	5.60	51.3
$[H^+]$ (x 10^{-8}) mol L^{-1}	3.3	5.3	8.2	10		17	24	

(b) Plot a graph of the K_w value versus temperature. (4 marks)



(c) Calculate the missing values for $[H^+]$ and complete the table above. (2 marks)

See next page

(d) Calculate the pH of water at 10°C and 40°C. (2 marks)

10°C:

40°C:

(e) Describe the relationship between K_w and temperature. (1 mark)

(f) From your graph, estimate the value of K_w at 45°C. (1 mark)

(g) What is the relationship between $[H^+]$ and temperature in pure water? (1 mark)

(h) Is water acidic, basic or neutral as temperature increases? Explain. (2 marks)

(i) From this data, is the ionisation of water an endothermic or exothermic reaction? Justify your answer. (3 marks)

See next page

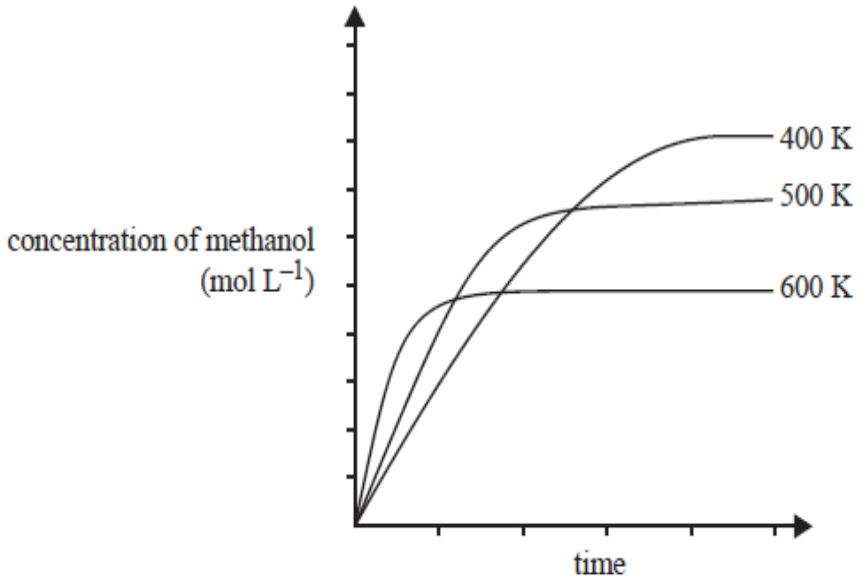
Question 39 **(12 marks)**

Methanol is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen and carbon monoxide at a temperature of 520 K and a pressure of 50 to 100 atmospheres. (1 atmosphere is equivalent to normal atmospheric pressure).

The reaction that occurs in the methanol converter is:

$$CO(g) + 2H_2(g) \rightleftarrows CH_3OH(g)$$

Carbon monoxide gas and hydrogen gas are mixed in a reaction vessel and equilibrium is established. The graph below shows how the concentration of methanol in this vessel changes with time at three different temperatures. The pressure is the same at each temperature.



(a) Deduce whether the forward reaction is exothermic or endothermic, making reference to Le Chatelier's Principle. (2 marks)

(b) Explain why, in practice, a moderately high temperature of 520 K is used. (2 marks)

See next page

(c) Explain why at a given temperature, the use of high pressure results in a greater equilibrium **concentration** and **rate** of production of methanol. (3 marks)

(d) A catalyst consisting of copper, zinc and aluminium is used to increase the rate of this reaction. Explain, using collision theory, how a catalyst increases the rate of this reaction. (3 marks)

The industrial process for the manufacture of methanol is not a closed system. The reactants are constantly fed into the reaction chamber and the products and unreacted reactants are passed into a cooling chamber. The methanol liquefies and is separated from the unreacted hydrogen and carbon monoxide and these gases are recycled into the reaction chamber.

(e) Why do industrial chemists use an open system, rather than a closed system, for the manufacture of methanol? (2 marks)

See next page

Question 40 **(16 marks)**

A student was investigating the reactivity of a series of unidentified metals, W, X, Y, Z and V, and their nitrate salts.. She carried out a series of experiments and recorded the following in her note book.

$W(s) + X^{2+}(aq) \rightarrow X(s) + W^{2+}(aq)$

$X(s) + 2Z^{+}(aq) \rightarrow X^{2+}(aq) + 2Z(aq)$

$Y(s) + X^{2+}(aq) \rightarrow X(s) + Y^{2+}(aq)$

$X(s) + V^{2+}(aq) \rightarrow X^{2+}(aq) + V(aq)$

$Y(s) + 2H_2O(l) \rightarrow Y^{2+}(aq) + 2OH^{-}(aq) + H_2(g)$

$W(s) + H_2O(l) \rightarrow$ NO REACTION

Metal V did not react with dilute hydrochloric acid all other metals did

(a) From this information, list the metals in order of increasing ease of oxidation. (3 marks)

Least likely to be oxidised _____ _____ _____ _____ _____ Most likely to be oxidised

(b) Identify the strongest oxidant in the reactions above. _____ (1 mark)

(c) The alkali metals, in Group 1, are all reducing agents. Explain why they are reducing agents and discuss the trend descending group 1, in terms of atomic structure and relevant atomic properties. (3 marks)

_____

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Sulfuric acid can act as an **oxidising** agent (oxidant). Depending on the conditions it can react in one of three ways to produce:

(i) sulfur dioxide
(ii) hydrogen sulfide gas , H_2S
(iii) elemental sulfur

(d) Write balanced half equations showing each of these possible reactions: (3 marks)

(i) _____

(ii) _____

(iii) _____

(e) Copper metal is able to dissolve in hot, concentrated sulfuric acid.

(i) Write the oxidation half equation for the dissolving of copper metal. (1 mark)

_____

(ii) Write the overall redox reaction between copper and hot concentrated sulfuric acid to produce **elemental sulfur**. (1 mark)

_____

_____

(iii) Write full observations for this overall redox reaction. (2 marks)

Observations: _____

_____

_____

(f) Can copper metal be oxidised by a 1.00 mol L^{-1} **dilute** solution of sulfuric acid? Explain your answer. (2 marks)

_____

_____

_____

_____

See next page

Question 41 **(15 marks)**

The sedimentary rock limestone consists almost entirely of two chemicals, calcium carbonate and silicon dioxide. Limestone sourced from the west end of Rottnest Island was analysed for its calcium carbonate content as follows:

(i) A 2.158 g sample of the limestone was pulverised and added to a beaker containing 200.0 mL of 0.294 mol L^{-1} hydrochloric acid solution.

(ii) The mixture was thoroughly stirred until no more effervescence was observed and only a small amount of insoluble residue was left at the bottom of the beaker.

(iii) 20.0 mL aliquots of the resulting solution were titrated against a standardised NaOH(aq) solution in the burette of concentration 0.118 mol L^{-1}

The results of successive titrations are given in the table below.

Titration	1st	2nd	3rd	4th
Final reading (mL)	20.20	37.65	21.65	39.05
Initial reading (mL)	1.50	20.20	4.15	21.65
Titre volume (mL)				

(a) Write an ionic equation for the reaction occurring when the limestone is mixed with the hydrochloric acid solution. (2 marks)

(b) With the aid of a calculation, explain why 200.0 mL of 0.294 mol L^{-1} hydrochloric acid solution was considered sufficient to dissolve all the calcium carbonate in the sample of limestone. (2 marks)

(c) Many oxides, such as magnesium oxide or copper oxide, dissolve in acids. Explain why silicon dioxide does not react with or dissolve in acidic solutions. (2 marks)

See next page

(d) Enter the values for titre volume in the table above and calculate an appropriate value for the average titre volume. (2 marks)

Average titre volume = _____

(e) Calculate the percentage by mass of calcium carbonate in the limestone sample. (7 marks)

Question 42 **(9 marks)**

Nitric acid can be produced from ammonia in a 3 step process, as shown below. The ammonia is first heated with oxygen, in the presence of a platinum/rhodium catalyst, to form nitric oxide and water. The nitric oxide is then oxidised further to nitrogen dioxide, which is then hydrated to form nitric acid.

Step 1: $4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$ ($\Delta H = -905$ kJ/mol)

Step 2: $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$ ($\Delta H = -114$ kJ/mol)

Step 3: $3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$ ($\Delta H = -138$ kJ/mol)

(a) Apart from nitric acid, what are the other two products of the overall process? (1 mark)

(b) If 300.0 moles of ammonia are reacted with an excess of other reagents, then state the number of moles of nitric acid produced. (3 marks)

(c) Briefly explain from where the energy needed to run a nitric acid plant may be sourced. (1 mark)

See next page

(d) If 2.50 tonnes of ammonia is reacted with excess oxygen, what mass of nitric acid will be produced, if step 3 of this process has a 90.0% yield? (Assume the other steps have 100% yield). (4 marks)

End of questions

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